05 eXtended new Reality

Fausto de Carvalho, Altice Labs
cfausto@alticelabs.com

Leonel Morgado, Universidade Aberta & INESC TEC
leonel.morgado@uab.pt

Ricardo Machado, Altice Labs
ricardo-j-machado@alticelabs.com

This article addresses some aspects of the potential of Extended Reality (XR) technologies in the context of the accelerated ongoing digital transformation, with public awareness and wider acceptance being prompted by current pandemic, due to the widespread adoption of teleworking, distance learning, and virtual conferences.
The state-of-the-art of XR technologies and immersive environments is briefly addressed from the perspective of their sustained adoption in multiple scenarios, including education and training, well-being and active aging, and business.

Keywords

AR; Augmented cognition; Immersion; Metaverse; MR; NUI; VR; XR

Introduction

Extended Reality (XR) is a term globally accepted to refer to the various flavors of combined real+virtual immersive environments and associated human-machine interaction through computers and wearables, a superset of the entire range along the reality-virtuality continuum [1], encompassing augmented reality (AR), virtual reality (VR), mixed reality (MR) and their subtle combinations and variations.

In recent decades, early adopters and enthusiasts of the fast-evolving XR technology developed a multiplicity of use cases around education, training, telepresence, serious gaming, and even pure entertainment and enjoyable communication among people around the globe. However, a certain level of complexity has slowed the general adoption of XR tools, even within professional contexts, with effective remote collaborative work falling far short of the maturity of technology. Videoconferencing (telepresence) remains the most notable exception, pushed forward by the general need to reduce travel.

In fact, just a couple of years back, VR environments and gadgets would make a lot of people immediately think about geeky atmospheres where time would be basically wasted in some costly gaming-like experience, ultimately perceived as a dangerous path of unhealthy isolation and escapism into a virtual life.

Suddenly, 2020 happened. And, day after day, due to pandemic concerns, we watch parents dueling for a time slot in the quieter room so that one can participate in video meetings with their co-workers while the other is also online but juggling children's dynamics at the same time: kids go around the house with their laptops, studying, attending classes online, meeting with their teachers, sneaking into social media and multi-user games. And then there are the online gym classes, the video calls with relatives, the video chats with friends, the online concerts, the online banking, online shopping, online everything: omnipresent technology and a walk on the wild side of digitalization and virtuality.

At some point, we will regain our full freedom to go out to the physical world and live free from imposed screens (albeit with our choice of carry-on screens), so we'll go back to schools, offices, pubs, museums, venues. Most likely, we will be using more and more XR technology everywhere, now that grown-ups in general (not just we geeky grown-ups) are willing to make the most of it, after getting acquainted and experienced on varied flavors of its effectiveness for keeping in touch without being bound to specific locations. This field is reaching a high level of maturity, and we can anticipate platforms and services that will allow us to be highly productive within this accelerating digital transformation context, while improving the balance among the multiple dimensions of happiness and quality of life.

Next, we delve into immersion and its relation to XR. Then we address technical and non-technical aspects that have been pushing this technological area ahead. Before wrapping up with some considerations about current trends and envisioned opportunities, we frame the evolution over the last decade, briefly reviewing some of our XR projects in specific areas: training and e-learning with virtual worlds; serious gaming for well-being and active aging; multimodal interaction and natural user interfaces (NUI); and XR for training, maintenance and other professional activities, including Digital Twins.

Immersion works indeed

When we dive into a book or movie and emotionally relate to its characters and narrative, to the point of feeling them more real (for those moments) than life, we are immersed. When we engage with a challenge at work or with a hobby to the point that night falls or the day breaks

without us realizing it, we are immersed. When technological gadgets buzz and pop around, detecting our motion, reminding us that stuff needs to be done, lighting up the public toilets we enter, we are immersed. When we close our eyes, insert earbuds, and experience spatial sound, we are immersed. And indeed, when we push onto our heads a virtual reality headset, we are immersed.

Immersion is mental absorption. It is "a phenomenon experienced by an individual when (...) in a state of deep mental involvement in which (...) cognitive processes (with or without sensory stimulation) cause a shift in (...) attentional state such that one may experience disassociation from the awareness of the physical world" [2] emerging from three different dimensions: the environment (including technology), the narrative one experiences, and the challenges one interacts with [3].

Immersion is our current state of being in the physical world; it also occurs naturally with good storytellers and engaging situations. When coupled with visual, auditory, and other cues, it is enhanced by embodiment (**Figure 1**), whereas we experience the perception of being within a virtual body, identifying a different self-location, to the point of identifying the virtual body parts as our own, even anticipating pain when they are hit - a perception that is driven and drives the user agency and engagement [5].

Technology has now enabled immersion and embodiment to be promoted, supported, and thus more reliably counted upon for effectiveness. Rather than expect readers and viewers to find themselves immersed in a narrative, immersive technology can empower that narrative with surrounding visuals, audio, and haptics, and transform readers and viewers into users, enabling their engagement and thus their sense of challenge.

Immersive technology thus is the key to effective use of immersion in work, education, and life in general. The affordances of technology lead to the subjective sense of being surrounded, upon

FIGURE 1 – Embodiment [4]

which the narrative and the challenges unfold [6]. And immersion, as we know from even pre-technological efforts [7], leads to effectiveness in engagement and understanding, promoting better and longer-lasting impacts. Therefore, it is expected that widespread use of immersion by leveraging technology can extend this effectiveness to all areas of society.

The single foremost driver of this immersion technology, in present days, is extended reality (XR): from smartphones and smart glasses that overlay virtual elements in our present world, to more powerful headsets such as Microsoft HoloLens, which can both free the user's hands for interaction with physical and virtual elements, and provide a quick reaction time in response to head motions, as mentioned in the next section.

Immersive technology has reached maturity

The Extended Reality ecosystem has been expanding very quickly, powered by the fast pace of evolution of information and communications technologies, and the market

is eagerly embracing the many technological options, despite some still being experimental. We are reaching a solid maturity level, enabling breakthrough platforms and services in the various flavors of VR, AR, and MR that seemed unattainable not long ago.

AR is already being used massively, often without people realizing it: Instagram and Pokémon GO are two of the most popular mobile apps, incorporating AR features to enhance user experience. Furthermore, this game and others alike (e.g., Ingress, Harry Potter Wizards Unite) are based on a global virtual overlay mapping directly onto real-world points-of-interest (POIs), bounding regular players to a pervasive feeling of persistent immersion, even while offline.

VR popularity has been growing steadily, but it's not yet considered mainstream. It's common to find VR headsets being used in marketing and advertising to suggest advance and modernity, albeit futuristic, which relates to the misleading general idea that this technology is still out of reach. Nevertheless, that may change rapidly, as popular brands with huge fan bases, such as Apple, start to roll out trendy products rumored to be already in production, with the expectable buzz and viral marketing.

When you think of VR headsets, you imagine bulky devices that stick to your face, connected to a big, powerful (and expensive) computer by a long cable. While this is true for some older devices, there are attractive options becoming available: VR headsets without cables, fully standalone, not requiring an external computer or tracking cameras installed in the room. These devices aren't tethered to a single point, therefore giving more freedom to the user, plus they have better screens and higher refresh rates, are lightweight, and generate less heat, so significantly reducing the chance of causing nausea.

It's possible to experience VR with almost zero investment, attaching a smartphone to a Google Cardboard or similar low-cost gadget, frequently available for free at tech events. While it is indeed a way to try out VR and 360-degree immersive video, it's certainly not a good experience due to the technical limitations: to achieve a more immersive and nausea-free VR experience, one needs six degrees of freedom (6DoF), meaning that the headset must track the translation (x,y,z) and rotation (pitch, yaw, and roll) of your head, and quick display response (almost instantly). This allows users to move freely around a virtual object to explore it from every angle and to come closer to inspect details, avoiding nausea. Additionally, having a way to interact with the virtual world, hands preferably, is important to enhance the sense of system immersion. That can be achieved with either two 6DoF controllers or having hands tracked by the headset itself. All of the above is already commercially available in some headsets for about 300 USD, the equivalent of a mid-range smartphone.

A healthy industry ecosystem is pushing technology forward and promoting innovation. Coming from a large mix of big companies and startups, and just naming a few, we have VR affordable headsets (Oculus Quest 2), and high-end devices (HTC Vive, HP Reverb G2), untethered cloud-powered MR headsets (Microsoft HoloLens 2) and AR/MR glasses almost indistinguishable from normal glasses (Nreal Augmented Reality glasses). Smartphone industry is, in fact, one of the key enablers of recent improvements on XR devices, with their small high-resolution screens and low-power powerful processors (e.g., Qualcomm Snapdragon XR2). And then there is a vast catalog of software and content, based on robust tools (e.g., PTC Vuforia Engine, Apple ARKit, Google ARCore) and driven by the quick technology adoption by the major 3D engines (Unity and Unreal), empowering thousands of enthusiastic developers.

Extended reality is (and has been) everywhere

Previous sections made evidence that XR is a multi-flavored technologically complex area, encompassing a medley of economic and human factors that have been frustrating a wider transposition of research and experimentation into market innovation [8]. Nevertheless, we have witnessed remarkable progress in terms of concepts, use cases, and technology in the last decade, from academia, startups, and industry, with big tech companies racing for strong positions in the ecosystem, aiming to conquer the huge emergent multi-billion market with their devices and/or development software platforms.

At Altice Labs, stemming from prior work at Portugal Telecom Inovação, we have relentlessly carried on exploratory projects addressing multiple dimensions and challenges on these subjects, mainly focused on advancing our knowledge and scrutinizing opportunities, but also to raise awareness and to collect precious feedback. We teamed mostly with academic partners to create a series of prototypes and proofs-of-concept, exposed to varied audiences in multiple contexts and events, of which we present below some highlights.

Our initial exploration of virtual worlds, around platforms such as Second Life and Open Simulator, was the basis for a set of projects (with UTAD, University of Trás-os-Montes e Alto Douro) to enhance the Formare [9] corporate learning management system (LMS) with immersive features blending these technologies with classical e-learning processes [10]. Fast-forwarding ten years, we currently see virtual worlds empowering massive live conferences online with over 3000 participants and high-profile speakers from industry and government, such as iLRN2020 [11] **(Figure 2)**.

The gaming industry has a long record of promoting video games, which are also a form of exercise (exergames), for platforms such as Microsoft Xbox, Nintendo Wii, and Switch consoles. In fact, natural user interfaces (NUI) leverage VR applied to e-Health, well-being, and active aging, allowing engaging applications for fitness, physiotherapy, and mental rehabilitation. Move4Health project (with Instituto de Telecomunicações de Aveiro, IT Aveiro) created a VR exergame based on real-time markerless motion capture, to assess the use of low-cost

FIGURE 2 – iLRN2020 6th International Conference of the Immersive Learning Research Network

devices (Kinect) for rehabilitation therapies based on gross motor skills. Furthermore, in Online Gym (with UTAD/INESC TEC), we successfully created and tested a prototype allowing multiple persons (elders, one over 80 years old) in different locations to participate via Kinect in shared, synchronized 3D gym classes in Open Simulator [12].

Once we perceived how critical natural interaction is, for several of our use cases with higher potential to thrive in the market, we focused on immersive multimodal interaction in the InMerse project (with UTAD/Universidade Aberta/INESC TEC): a gesture-controlled digital signage prototype led to relevant results as a flexible software architecture [13]. This empowered a game/installation prototype that explored user experience (UX) and multi-user interaction: two players with different devices, roles, and locations, sharing gestures and playing within a 3D scenario set around the fictional epic episode of Adamastor during the Portuguese Age of Discovery [14].

Recent work has taken the challenge of empowering users further by leveraging their rich, intuitive understanding of cultural gestures and rituals to command immersive environments: the Shamanic interface concept [15], which has proven in controlled lab experiments to be extremely effective for users' ability to interact [16].

XR is the latest development in what traditionally was seen as VR or AR. The convergence of head-mounted displays (e.g., Oculus Rift) and camera-empowered devices, such as smart glasses (e.g., Google Glass) or smartphones, led first to MR, the convergence of VR and AR into a single device, and from there to the ambition of freeing the user for interaction and providing seamless blending of the virtual with the physical: XR. This seamlessness was made possible in two ways: by powerful, lightweight devices, such as Microsoft HoloLens, and by a combination of wall-sized projection and motion detection, such as CAVE systems [17]. We employed this in project ARaNI (with UTAD/INESC TEC) in a prototype for joint collaborative interaction over a 3D virtual human body model.

In another ARaNI prototype, we tested a Smart Mirror as a possible AR platform, with a necktie teaching application.

We also explored a novel approach to VR: created after a company repurposing challenge, the Immersive Phone Booth prototype **(Figure 3)** was available in early 2020, allowing 360-degree video immersive visualization.

FIGURE 3 – Immersive Phone Booth (Altice Labs 2020)

Until now, simpler AR/MR use cases for training, maintenance, field operations, and other professional activities have been higher in the ranking of successful XR deployments, despite so much amazing technology and many ingenious applications shown regularly in events and conferences. Digital Twins, accurate dynamic virtual representations of physical entities, are gaining momentum in Industry 4.0, and we have pursued this domain as well, with some AR/VR proofs of concept, such as an immersive robot arm controller. In fact, this is an area that relates directly to early work around role-playing in virtual worlds: the development of a mechanical maintenance training simulator in OpenSimulator for F-16 aircraft engines [18] developed by UTAD & INESC TEC (see **Figure 4**).

FIGURE 4 – XR in Industry 4.0 context [18]

What are the frontiers of opportunity and challenges?

So, what's next? As ever, any forecast is risky, especially in this area that has been promising so much for so long without actually getting there. Still, the ongoing workplace transformation is pushing a series of technological trends that many analysts seem to agree on [19], and we need no crystal ball to tell us that the significant increase in teleworking will have a strong impact on decision-making at home and beyond.

5G is arriving and it's poised to be a game-changer for XR, paving the way for powerful distributed processing capabilities across the edge, the network, and the cloud, available pervasively to portable connected devices with tangible UIs, with negligible latency. Furthermore, massive deployment of internet of things (IoT) is surrounding us with a plethora of sensors, gathering (big) data and allowing insights and intelligent responsiveness through machine learning and real-time context-aware analytics, enabling the enhancement of the physical world around us by a dynamic, persistent virtual space that can be perceived consistently and shared collectively - a metaverse where Augmented Cognition is, in fact, a novel dimension of immersivity.

Ultimately, we are moving towards immersive environments where technology ceases to be special and becomes pervasive. That is, technology bridges the mental context (needs, preferences, prior knowledge) with the physical and virtual contexts, becoming seamless [20]. This will create new opportunities for services in a renewed ecosystem that digitally crosses our lives at homes, schools, businesses, and the city itself.

Currently, we can identify hindrances still interfering with the expected progress, for example, ergonomic factors, the cost of devices, and their autonomy. The diversity of stakeholders involved in these broader XR scenarios will require reliable, collaborative frameworks to address issues such as effective management, interoperability, security, and privacy. These are priorities acknowledged by researchers and practitioners alike in a recent survey of the field priorities [21].

There is also the need to tackle problems arising from the massive incorporation of AI-based features, and there are even new challenges just emerging, inherent to the intense immersion itself. Nevertheless, we have been witnessing that for each iteration, each cycle, we firmly advance in the right direction, so we may confidently state that, more and more, work and living will become further atopic: not located at any specific location or set of locations, but rather in a wide metaverse of virtuality (see **Figure 5**).

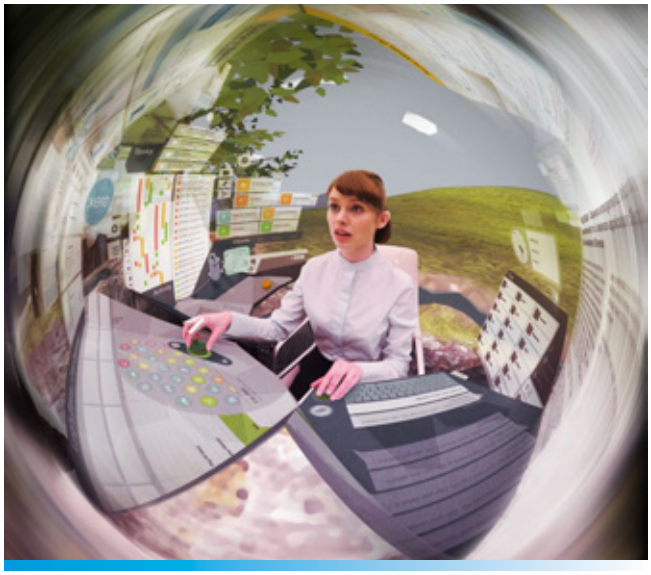

FIGURE 5 – The Future of Work [22]

References

[1] P. Milgram, H. Takemura, A. Utsumi, and F. Kishino, "Augmented reality: a class of displays on the reality-virtuality continuum," Boston, MA, Dec. 1995, pp. 282–292, doi: 10.1117/12.197321

[2] S. Agrawal, A. Simon, and S. Bech, "Defining Immersion: Literature Review and Implications for Research on Immersive Audiovisual Experiences," in 147th AES Pro Audio International Convention, New York, 2019, p. 14

[3] N. C. Nilsson, R. Nordahl, and S. Serafin, "Immersion Revisited: A review of existing definitions of immersion and their relation to different theories of presence," Hum. Technol., vol. 12, no. 2, pp. 108–134, Nov. 2016, doi: 10.17011/ht/urn.201611174652

[4] M. Pesce, "Razer OSVR Open-Source Virtual Reality for Gaming", 2015. https://commons.wikimedia.org/wiki/File:Razer_OSVR_Open-Source_Virtual_Reality_for_Gaming_(16863422875).jpg

[5] K. Kilteni, R. Groten, and M. Slater, "The Sense of Embodiment in Virtual Reality," Presence Teleoperators Virtual Environ., vol. 21, no. 4, pp. 373–387, Nov. 2012, doi: 10.1162/PRES_a_00124

[6] D. Beck, L. Morgado, and P. O'Shea, "Finding the Gaps about Uses of Immersive Learning Environments: A Survey of Surveys," J. Univers. Comput. Sci., in press

[7] E. L. Robinson, "Immersion Learning in Social Work Education: A Pedagogical Tool for Enriching Knowledge and Practice Skills among BSW Students," J. Teach. Soc. Work, vol. 38, no. 5, pp. 536–550, Oct. 2018, doi: 10.1080/08841233.2018.1516712

[8] S. H. W. Chuah, "Wearable XR-technology: literature review, conceptual framework and future research directions," Int. J. Technol. Mark., vol. 13, no. 3/4, p. 205, 2019, doi: 10.1504/IJTMKT.2019.104586

[9] "Formare", Altice Labs, 2020. https://www.alticelabs.com/site/formare/

[10] L. Morgado et al., "Requirements for the use of virtual worlds in corporate training : perspectives from the post-mortem of a corporate e-learning provider approach of Second Life and OpenSimulator," ILRN 2016 Immersive Learn. Res. Netw. Conf. Workshop Short Pap. Poster Proc. Second Immersive Learn. Res. Netw. Conf., pp. 18–29, 2016

[11] "iLRN 2020", Immersive Learning Research Network, 2020. https://immersivelrn.org/ilrn2020/

[12] L. Morgado et al., "Online-Gym: Multiuser virtual gymnasium using RINIONS and multiple kinect devices," 2014, doi: 10.1109/vs-games.2014.7012164

[13] L. Morgado et al., "Separating Gesture Detection and Application Control Concerns with a Multimodal Architecture," in 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing, 2015, pp. 1548–1553, doi: 10.1109/cit/iucc/dasc/picom.2015.233

[14] L. Morgado et al., "Exploring educational immersive videogames: an empirical study with a 3D multimodal interaction prototype," Behav. Inf. Technol., pp. 907–918, 2016, doi: 10.1080/0144929x.2016.1232754

[15] L. Morgado, "Cultural awareness and personal customization of gestural commands using a shamanic interface," Procedia Comput. Sci., vol. 27, pp. 449–459, 2013

[16] P. Carvalho, "Experiment in Human-Computer Interaction - Evaluation of a Shamanic Interface for Interaction with Cultural Gestures in Virtual Environments," Master dissertation, Faculdade de Engenharia da Universidade do Porto, Porto, Portugal, 2019

[17] S. Manjrekar, S. Sandilya, D. Bhosale, S. Kanchi, A. Pitkar, and M. Gondhalekar, "CAVE: An Emerging Immersive Technology -- A Review," in 2014 UKSim-AMSS 16th International Conference on Computer Modelling and Simulation, Cambridge, United Kingdom, Mar. 2014, pp. 131–136, doi: 10.1109/UKSim.2014.20

[18] A. Pinheiro et al., "Development of a mechanical maintenance training simulator in OpenSimulator for F-16 aircraft engines," Entertain. Comput., vol. 5, no. 4, pp. 347–355, Dec. 2014, doi: 10.1016/j.entcom.2014.06.002

[19] M. Rimol, "6 Trends on the Gartner Hype Cycle for the Digital Workplace, 2020," Smarter with Gartner, Aug. 24, 2020. https://www.gartner.com/smarterwithgartner/6-trends-on-the-gartner-hype-cycle-for-the-digital-workplace-2020/

[20] A. Coelho et al., "Serious Pervasive Games," Front. Comput. Sci., vol. 2, p. 30, Aug. 2020, doi: 10.3389/fcomp.2020.00030

[21] H. Gaspar, L. Morgado, H. Mamede, T. Oliveira, B. Manjón, and C. Gütl, "Research priorities in immersive learning technology: the perspectives of the iLRN community," Virtual Real., vol. 24, pp. 319–341, 2020, doi: 10.1007/s10055-019-00393-x

[22] K. Matsuda, Merger. 2018. http://km.cx/projects/merger